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A PRELIMINARY NOTE ON ANT BEHAVIOR.

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There is a wide-spread belief among living entomologists that ants slavishly follow the odor trail and Bethe insists that ants are mere reflex machines. For something over three years I have been conducting a series of experiments on the behavior of ants, the results of which do not harmonize with the above view. These experiments, which were performed upon a large number of southern species and a few northern species, show conclusively :

1. That the movements of worker ants are not controlled by tropisms.

2. That ants are not guided by a homing instinct.

3. That ants are enabled to take long trips by learning, by experience, the way and retaining what they have thus acquired. They learn the way in the same manner that vertebrates learn to open problem boxes and to run mazes.

4. That ants do not as slavishly follow the odor trail as is supposed.

5. That Sir John Lubbock was right when he said : " In determining their course ants are greatly influenced by the direction of the light."

6. The color of the pathway has little or no effect upon the home-going of ants.

7. That Dr. Wheeler is right in stressing the high development of the female ; for the winged females often take part in the regular duties of the nest. I have had them learn the way home from new situations and assist the workers in carrying the pupæ home.

8. That the males are stupid and seem unable to solve even the simplest of problems. They seem to be more or less heliotropic.

9. The major workers of *Pheidole*, which Ernest Andre claims function as soldiers and do not take any active part in the ordinary work of the nest, frequently assist the workers in making

excavations ; and, occasionally, assist in conveying pupæ from one place to another. I have never noticed one continue to carry pupæ for any considerable length of time.

10. Ants are affected by olfactory, optic, tactile, kinesthetic and probably auditory stimuli.

11. Ants seem to have fairly definite impressions of direction, both in horizontal and vertical planes, and of distance.

12. Ants have associative memory.

13. Such cases of division of labor as Romanes — quoting from Moggridge, Lespes, Belt and Herr Gredler — describes in his "Animal Intelligence," are to be looked upon as cases of incidental coincidence rather than as examples of mutual coöperation.

14. Ants can be trained to do certain simple things in the same way that vertebrates are trained.

15. In their activities ants display marked individual variations

In this preliminary paper, space forbids a discussion of the data upon which the above statements are based ; that will be done in a paper which I expect to publish in the spring or summer of 1907. In this communication I merely desire to give some of the evidence that warrants the fourth and fifth statements.

In these experiments I used a card-board stage six inches square, from which a card-board incline, three fourths of an inch wide, led down to the island upon which the nest of the ants was confined. A great many pupæ and worker ants were placed on this stage. After many random movements the ants learned the way from the stage to the nest and back. The way once learned, the ants continued to work until all of the pupæ had been carried into the nest. I then replaced the ants and pupæ on the stage. The pupæ were again carried home. This was repeated over and over again ; until, by their actions, I concluded that the ants were thoroughly acquainted with the way down the incline to the nest. Then a second incline was so placed as to lead from the opposite side of the stage to the Lubbock island. If, after a lapse of a few minutes, no workers descended this second incline, I concluded that the workers thoroughly knew the way down the other path. I then placed the first incline, which had

become scented by the foot-prints of the ants, in the place where the new incline had been and placed a new unscented incline in the place formerly occupied by the one the ants had been traversing. Thus there was an unscented path in the position of the old trail and the old familiar scented path was in a new position.

Now if ants are guided home solely by the sense of smell, they should either have spent approximately as much time learning the way down the new incline as they did before; or else, in their random movements, they should have happened upon the scented incline and gone down it. In reality, they did neither of these things. They went almost immediately down the unscented incline which occupied the position in space formerly filled by the incline down which they had been carrying pupæ to the nest.

Similar experiments, yielding the same results, were conducted with marked individual ants.

It will be seen at once that these experiments disprove not only Bethe's double polarized trail hypothesis but also Wasmann's assumption that their odor tracks have for ants an odor-shape which guides them home.

According to the current belief, ants going to and from my stages should have followed the same path. But experiments, conducted with marked individual ants, showed that this was not always the case. I found:

1. That the ant had to learn the way, not only from the stage to the island, but also from the nest back again to the stage and that it usually required more time to solve the second problem than it did to solve the first.
2. That sometimes an ant would regularly descend to the island along the top side of the incline and ascend to the stage along the under side of the same incline.
3. I have noticed a worker regularly descend from the stage by way of the incline and ascend the stage by way of its central support.
4. I have had ants ascend to the stage by way of one incline and descend by the other.
5. In passing from the nest to the foot of the incline the ant did not always follow the same path.

6. I have known an ant to regularly drop from the stage with a pupa and carry it to the nest and then return to the island, mount a section lifter, which I presented, and rest quietly thereon until it had been conveyed to the stage. Then it would step off, pick up a pupa and drop from the stage. This was repeated over and over again by the ant.

More than a quarter of a century ago Lubbock claimed that ants were influenced by the direction of the rays of light. These experiments have been either overlooked or ignored by recent continental writers. Although Sir John Lubbock's experiments were not so planned as to exclude the possibility of the effect noticed having been produced by heat or change in the intensity of light, yet it is hard to see any reason why they should have been so completely ignored by European writers. My experiments on the effect of light upon the home-going of ants, which were conducted under perfectly planned conditions of control, resemble very much certain of Lubbock's experiments.

Two kinds of tests were conducted: experiments with ants working in concert, and experiments with marked individual ants working alone.

In experiments of the first type a card-board stage was used, from which a card-board incline led down to the island. A 16 c. p. incandescent lamp was placed near the side to which the inclined plane was attached. After the ants had thoroughly learned the way home, a new incline was attached to the stage on the side opposite the one to which the old incline was still attached. If, after a lapse of five minutes, no ants went down the new incline, conditions were considered right for the test. The light was then transferred to the opposite side of the stage. In each test the halting movements of the ants showed that they were much disturbed. In most cases, some of the ants would finally go down the new incline; and in a few cases, after the lapse of several minutes, all of the ants went down the new incline. The above described experiments with ants working in concert were conducted with several different species.

The individual experiments to test the same thing were conducted with *Formica fusca* var. *subsericea* Say and *Myrmica punctiventris* Rog. The apparatus was arranged in the same manner

as for ants working in concert ; but, marked ants were used and only one was allowed to work at a time. In all essential points, the results harmonized with those obtained from ants acting in concert. In most cases, however, after a greater or lesser lapse of time, the ant would usually find its way down the old incline to the nest ; and, after a greater lapse of time, find its way back again to the stage.

That the above effect was not due to heat was proven in the following manner. At the right and left of the stage used was placed a tall museum jaw .34 cm. \times 16 cm. \times 17 cm., filled with distilled water. These heat filters were so adjusted as to have their broad sides parallel to the edges of the stage. At the beginning of the experiment, a 32 c. p. incandescent lamp was placed behind one of these filters (usually behind the one that was near the incline). After the ants had traveled the path long enough to make the trips regularly and rapidly, the lamp was transferred to behind the opposite filter. In every case the workers were much disturbed in the manner stated above. This was repeated with seven different colonies of *Formica fusca*. Since the heat had been excluded, it is evident that the disturbance was the result of some form of light stimulus.

To determine whether the intensity or the direction of light was the determining factor, the experiment was slightly modified. The stage and incline were arranged as before. Sometimes the heat filters were used, but more often they were not. To furnish illumination, four different candle powers (4 c. p., 8 c. p., 16 c. p., 32 c. p.) of incandescent lamps were used, one at a time, in a darkened room. At the beginning of the experiment a lamp of a certain candle-power was placed near the side of the stage to which the incline was attached. After the ants had thoroughly learned the way home a different candle-power was substituted for the first. After the lapse of a few more minutes this lamp was transferred to near the opposite side of the stage. Shortly it was returned to its former position. A few minutes later a different candle-power was substituted for this. This performance was repeated over and over again until each candle-power had been used one or more times.

It was found that substituting a lamp of one candle-power for

a lamp of a different candle-power had no disturbing effect upon the actions of the ants; but that by any marked change in the angular position of the light, no matter what the candle-power, the ants were much disturbed. This forces us to the conclusion that the direction of the rays of light, when present, plays a prominent rôle in the home-going of ants.

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